MEDICAL CARE
November-December 1973, XI, No. 6

Original Articles

Allied Health Manpower Strategies:

Estimates of the Potential Gains from Efficient Task Delegation

FREDERICK L. COLLADAY, PH.D.,* MARIANNE MILLER, M.S.,† AND KENNETH R. SMITH, PH.D.‡

This study analyzes the potential impact of physician extenders on the productivity of primary care practices and considers the consequent implication for future health manpower requirements. A number of previous investigations have evaluated a variety of extenders in experimental settings. This study, in contrast, constructs and operates a simulation model of the representative practice permitting one to synthesize the experiences and insights of earlier demonstration projects. The model requires the practice to delegate tasks to paramedical personnel including the physician extender in such a way as to minimize the total cost of delivering a list of required medical services. The alternative acceptable techniques for delivering care are defined by the number of minutes of each type of medical personnel that must be employed in producing each service. Primary care is characterized by distinct medical services.

The model reveals that physician extenders could increase the productivity of a representative primary care practice by up to 74 per cent. Alternatively, the commitment of physician time required to serve a patient load of 100 visits a week might be reduced by 14.2 hours through effective use of an extender. The article concludes with observations on the implications of physician extenders for future health manpower requirements.

THE DEMAND FOR MEDICAL SERVICES is increasing dramatically. As public and private insurance schemes develop to cover the costs of care, the demands on the health care system will expand further. These expanded demands have prompted experts to propose that additional resources be allocated towards existing programs of physician training. Such proposals are premised on the the assumption that the current organization of the health care system will continue indefinitely. However, in view of the extraordinary cost of medical education and the great length of time required to develop new training programs, it seems appropriate to explore alternative strategies for the expansion of medical services.

Considerable interest has developed within the medical profession in task delegation and in the training of new classes of

The project upon which the paper is based was performed pursuant to Contract No. HSM 110-70-355 with the Health Services and Mental Health Administration, U. S. Department of Health, Education, and Welfare. An earlier draft of the paper was presented to the American Public Health Association Annual Meeting, Special Session on Health Manpower Planning, October 14, 1971, in Minneapolis, Minnesota.

*Assistant Professor of Economics, Health Economics Research Center, Department of Economics, University of Wisconsin, Madison, Wisc. 53706.

†Doctoral candidate.

‡Associate Professor of Economics, The University of Wisconsin, Madison, Wisc.

health workers as means of increasing the productivity of the physician.[1] During the past decade over 100 programs have emerged to train various types of physician extenders. Those involved in the development of these programs postulate that much of the activity of the practicing physician is highly repetitive and requires much less training and clinical expertise than he possesses. The productivity of the physician might, therefore, be increased substantially by allowing specially trained physician extenders to assume these responsibilities.[2] Clearly, increasing the physician's productivity is an alternative to increasing his numbers. Therefore, the use of paraprofessional medical workers to deliver health care has profound implications for future health manpower needs. Before important decisions regarding future training programs for physicians and physician extenders are made, it would be useful to analyze the implications of delegation and to assess the impact of new categories of personnel on health manpower requirements.

This paper describes an exploratory study of the optimal role of the physician's assistant (P.A.) in primary care practice and the implied manpower strategy. A model of the primary care practice is developed which simulates the behavior of an efficiently run practice in which the delegation is permitted. The analysis identifies the least cost program of staffing and the resulting pattern of delegation required to produce the medical services demanded by patients in a representative general practice.

The following sections of this paper 1) present the analytic model, 2) discuss the ways in which it may be used to explore the implications of proposed patterns of task delegation, 3) describe the data requirements of the study and the methods employed in obtaining them, 4) present some preliminary empirical results, 5) discuss the implications of these results for a health manpower strategy, and 6) suggest possible extensions of the study. A formal presentation of the analytic model is found in the appendix.

Analytic Model of the Office Practice

The primary care practice is represented analytically as a firm that utilizes the time of various medical personnel to produce medical services. The practice is required to produce the medical services which respond to the needs of its patient population and it must produce these services by methods known to be satisfactory. The medical services required are expressed by the percentages of total patient visits which fall in each medical service category and the total number of patient visits per period. In general, a number of equally acceptable methods are available for producing a particular medical service. Each method is defined by specifying the number of minutes of each type of medical personnel that must be utilized in producing one unit of that service. The physician-entrepreneur is assumed to commit a fixed amount of time to medical contact in the practice setting. His objective is to minimize the variable costs of the nonphysician personnel necessary to produce the medical services required. Given these constraints on demand the methods for producing each service and the physician time available, the model solves for the most efficient (least cost) utilization of health manpower.

At very low levels of activity, it may be possible for the physician to practice without assistance. Opportunities for delegation will not be exercised because they are costly and, given the available physician time, unnecessary. As the scale of the practice expands, however, assistants will be hired to enable the physician to service the demands of his patients. Eventually, further expansion of the practice will be infeasible since the opportunities for delegation are limited and the available physician time is fixed. As the practice size increases, the cost to the physician will rise since he will delegate more activities to assistants; yet, for each scale of the practice, the utilization of personnel chosen by the model will represent the least costly way of meeting that level of demand.

Insights from the Model

A number of important issues may be addressed with the model. The most obvious issue concerns the potential effect upon the productivity of the physician of introducing the P. A. into the health care system. This question may be addressed by contrasting the results of the model when the utilization of the P. A. is and is not permitted. Excluding the P. A. eliminates a number of methods for delivering various medical services and hence reduces the flexibility of the practice. The contrast between the inclusion and exclusion of the P. A. reveals the potential increase in volume of services that can be anticipated from the economic use of the P. A.

The implications of restricting the use of the P. A. in the practice may be considered by deleting from the model any methods which are prohibited by law or medical custom. The results of the analysis with and without the restrictions indicate the impact of the restraints on physician productivity and the pattern of delegation. The model also provides a framework for analyzing the impact of techniques which have not yet been experimentally observed. Hypothetical methods of producing various services may be incorporated into the model and their consequences evaluated.

The relation of the optimal (most economic) pattern of delegation to the size of the medical practice may also be examined. As the practice expands, the model periodically reorganizes the pattern of staffing in order to increase its output. The solution to the model at each level of output indicates the most efficient methods for delivering specific types of care. Since these methods are expressed in terms of different combinations of staff time, they indicate the functions assigned to each member of the health care team and the skills each should possess. This facilitates the planning of training programs for physician's assistants.

This orientation suggests the diversity of policy-relevant insights that may be derived from analyzing the solutions of the model. The model enables one to explore health manpower needs and training requirements in a rational health care system. In contrast, the literature on health manpower planning relies upon historically observed ratios of health manpower to population in projecting future manpower needs. The traditional approach fails to explore the potential variations in the health manpower pyramid. In view of the extraordinary costs of establishing and operating medical training programs, this failure is a fundamental criticism.

Empirical Basis for the Study

The analysis described above requires a substantial volume of highly detailed information on the composition of demand and the methods available for delivering particular medical services. Because little empirical research has been devoted to studying the activities of the primary care practice, it was necessary to design and conduct a survey of medical activity. Practices surveyed by medical students for two-week periods included urban and rural, group and solo practices in Wisconsin, Vermont, and North Carolina. Two of the practices employed physician's assistants. A comprehensive statement of tasks performed in a primary care practice was devised enumerating 263 tasks in eight major categories of activity ranging from taking histories to performing office surgeries. Key characteristics of each patient visit were gathered and observers recorded

TABLE 1. Demand for Services

Services	Number per 1,000 Cases
Physical Examination	
Well child (age 0–1)	40
Well child (age 1–16)	141
Abbreviated	30
Complete female	24
Complete	55
Complete with ECG	14
Prenatal Examination	
Routine	42
With genetic counseling	14
First visit—pregnancy	10
Birth control—female problem	10
Desensitization shots	56
Skin allergy	30
Immunization	47
Sore throat	54
Otitis externa and media	47
Sinusitis	30
Thrombophlebitis	2
Hematoma	1
Remove ear wax	15
Warts	
Excise	7
Follow-up	7
Urinary infection	4
Heart disease	2
Exogenous obesity	21
Hypertension	
Routine	11
Elderly	3
Fractures	18
Lacerations	
First visit	4
Check and redress	26
Remove sutures	20
Muscle contusion	
With X-ray	5
Without X-ray	8
Muscle pain	8
Burns	8
Abscess	8
Wound infections	12
Arthritis	6
All other services	176

at one-minute intervals what task was being performed and the type of medical personnel involved.[3]

Task information was combined with information on diagnosis and chief complaint to identify the medical services being delivered. While it is true that many tasks are potentially delegable, simply evaluating delegation with respect to tasks fails to capture the importance of sequencing in determining the feasibility of delegation. In producing a particular medical service, a number of things are happening simultaneously, the most obvious of which is the performance of physical tasks by medical personnel. Consideration must also be given to the relationship between the physician and his co-workers, since the information necessary in making the medical decision is being gathered and processes. In addition, the total relationship between the patient and medical care team must be recognized. While these additional factors do not in themselves prevent delegation, they do impose a limit on the degree of fragmentation of tasks among the various medical personnel. Optimizing with respect to medical services assures that the pattern of delegation chosen by the model will be practical from a medical point of view.

Forty-one medical services were identified from the survey data. It was possible to assign 83 per cent of the total patient visits to these medical service categories. The remaining visits were unclassifiable with available information. The list of services demanded and the frequency of each for an urban clinical practice are shown in Table 1.

The task profile obtained for each patient visit and the knowledge of who performed each task made it possible to identify the various methods available for delivery of a particular service. Each method is a unique combination of medical personnel time. Because staffing patterns varied among practices observed, it was possible to identify several methods for each service. It was assumed that all the methods observed were medically ac-

TABLE 2. Alternative Techniques for Producing Medical Services

Service	Production Technique	Minutes of Personnel Time Required To Produce One Unit of Service[a]						
		MD	RN	LPN	Med Asst.	X-ray Tech	Lab Tech	PA
Physical examinations								
Well child (0–1)	a	10	0	0	0	0	0	0
	b	7	4	0	0	0	0	0
	c	7	0	4	0	0	0	0
	d	7	0	0	4	0	0	0
Well child (2–16)	a	14	0	0	0	0	0	0
	b	0	0	0	0	0	0	14
	c	10	5	0	0	0	0	0
	d	0	5	0	0	0	0	10
Abbreviated physical	a	8	0	0	0	0	0	0
	b	7	5	0	0	0	0	0
	c	7	0	5	0	0	0	0
	d	7	0	0	5	0	0	0
Complete female checkup	a	24	0	0	0	0	0	0
	b	21	4	0	0	0	0	0
	c	21	0	4	0	0	0	0
	d	21	0	0	4	0	0	0
Complete physical	a	14	0	0	0	0	0	0
	b	10	5	0	0	0	0	0
	c	10	0	5	0	0	0	0
	d	10	0	0	5	0	0	0
Physical with ECG	a	34	0	0	0	0	0	0
	b	18	17	0	0	0	0	0
	c	18	0	17	0	0	0	0
	d	18	0	0	17	0	0	0
	e	18	0	0	0	0	17	0
Prenatal examinations								
Routine	a	10	0	0	0	0	0	0
	b	8	3	0	0	0	0	0
	c	8	0	3	0	0	0	0
	d	8	0	0	3	0	0	0
With genetic counseling	a	22	0	0	0	0	0	0
	b	20	3	0	0	0	0	0
	c	20	0	3	0	0	0	0
	d	20	0	0	3	0	0	0
First visit—pregnancy	a	13	0	0	0	0	0	0
	b	11	3	0	0	0	0	0
	c	11	0	3	0	0	0	0
	d	11	0	0	3	0	0	0
	e	11	0	0	0	0	3	0
Birth control—female problems	a	15	0	0	0	0	0	0
	b	14	2	0	0	0	0	0
	c	14	0	2	0	0	0	0
	d	14	0	0	2	0	0	0
Desensitization shots	a	4	0	0	0	0	0	0
	b	0	4	0	0	0	0	0
	c	0	0	4	0	0	0	0
	d	0	0	0	0	0	0	4
Skin allergy	a	6	0	0	0	0	0	0
	b	0	0	0	0	0	0	6
Immunization	a	3	0	0	0	0	0	0
	b	0	3	0	0	0	0	0
	c	0	0	3	0	0	0	0
	e	0	0	0	3	0	0	0
	d	0	0	0	0	0	3	0
	f	0	0	0	0	0	0	3

TABLE 2. (Continued)

Service	Production Technique	Minutes of Personnel Time Required To Produce One Unit of Service*						
		MD	RN	LPN	Med. Asst.	X-ray Tech	Lab Tech	PA
Sore throat	a	8	0	0	0	0	0	0
	b	0	0	0	0	0	0	8
	c	7	2	0	0	0	0	0
	d	7	0	2	0	0	0	0
	e	7	0	0	2	0	0	0
	f	7	0	0	0	0	2	0
	g	0	2	0	0	0	0	7
	h	0	0	2	0	0	0	7
	i	0	0	0	2	0	0	7
	j	0	0	0	0	0	2	7
Otitis externa and media	a	10	0	0	0	0	0	0
	b	0	0	0	0	0	0	10
	c	9	2	0	0	0	0	0
	d	9	0	2	0	0	0	0
	e	9	0	0	2	0	0	0
	f	0	2	0	0	0	0	9
	g	0	0	2	0	0	0	9
	h	0	0	0	2	0	0	9
Sinusitis	a	9	0	0	0	0	0	0
	b	0	0	0	0	0	0	9
	c	8	2	0	0	0	0	0
	d	8	0	2	0	0	0	0
	e	8	0	0	2	0	0	0
	f	0	2	0	0	0	0	8
	g	0	0	2	0	0	0	8
	h	0	0	0	2	0	0	8
Thrombophlebitis	a	12	0	0	0	0	0	0
	b	11	2	0	0	0	0	0
	c	11	0	2	0	0	0	0
Hematoma	a	11	0	0	0	0	0	0
	b	10	2	0	0	0	0	0
	c	10	0	2	0	0	0	0
	d	10	0	0	2	0	0	0
Remove ear wax	a	6	0	0	0	0	0	0
	b	0	0	0	0	0	0	6
	c	5	2	0	0	0	0	0
	d	5	0	2	0	0	0	0
	e	5	0	0	2	0	0	0
	f	0	2	0	0	0	0	5
	g	0	0	2	0	0	0	5
	h	0	0	0	2	0	0	5
Warts								
Treatment	a	18	0	0	0	0	0	0
	b	0	0	0	0	0	0	18
	c	16	3	0	0	0	0	0
	d	16	0	3	0	0	0	0
	e	16	0	0	3	0	0	0
	f	0	3	0	0	0	0	16
	g	0	0	3	0	0	0	16
	h	0	0	0	3	0	0	16
Follow-up	a	8	0	0	0	0	0	0
	b	0	0	0	0	0	0	8
	c	6	3	0	0	0	0	0
	d	6	0	3	0	0	0	0
	e	6	0	0	3	0	0	0
	f	0	3	0	0	0	0	6
	g	0	0	3	0	0	0	0
	h	0	0	0	3	0	0	6

TABLE 2. (Continued)

Service	Production Technique	Minutes of Personnel Time Required To Produce One Unit of Service*						
		MD	RN	LPN	Med. Asst.	X-ray Tech	Lab Tech	PA
Urinary infection	a	11	0	0	0	0	0	0
	b	0	0	0	0	0	0	11
	c	9	3	0	0	0	0	0
	d	9	0	3	0	0	0	0
	e	9	0	0	3	0	0	0
	f	0	3	0	0	0	0	9
	g	0	0	3	0	0	0	9
	h	6	0	0	3	0	0	9
Heart disease	a	16	0	0	0	0	0	0
	b	12	5	0	0	0	0	0
	c	12	0	5	0	0	0	0
	d	12	0	0	5	0	0	0
Exogenous obesity	a	9	0	0	0	0	0	0
	b	0	0	0	0	0	0	9
	c	7	3	0	0	0	0	0
	d	7	0	3	0	0	0	0
	e	7	0	0	3	0	0	0
	f	0	3	0	0	0	0	7
	g	0	0	3	0	0	0	7
	h	0	0	0	3	0	0	7
Hypertension								
Routine	a	10	0	0	0	0	0	0
	b	8	3	0	0	0	0	0
	c	8	0	3	0	0	0	0
	d	8	0	0	3	0	0	0
Elderly	a	17	0	0	0	0	0	0
	b	15	3	0	0	0	0	0
	c	15	0	3	0	0	0	0
	d	15	0	0	3	0	0	0
Fractures	a	10	0	0	0	0	0	0
	b	8	3	0	0	0	0	0
	c	8	0	3	0	0	0	0
	d	8	0	0	3	0	0	0
	e	8	0	0	0	3	0	0
Lacerations								
First visit	a	16	0	0	0	0	0	0
	b	13	4	0	0	0	0	0
	c	13	0	4	0	0	0	0
	d	13	0	0	4	0	0	0
Check and redress	a	8	0	0	0	0	0	0
	b	5	4	0	0	0	0	0
	c	5	0	4	0	0	0	0
	d	5	0	0	4	0	0	0
Remove sutures	a	5	0	0	0	0	0	0
	b	0	0	0	0	0	0	5
	c	0	5	0	0	0	0	0
Muscle contusion								
With X-ray	a	11	0	0	0	0	0	0
	b	8	0	0	0	4	0	0
	c	5	3	0	0	4	0	0
	d	5	0	3	0	4	0	0
	e	5	0	0	3	4	0	0

TABLE 2. (Continued)

Service	Production Technique	MD	RN	LPN	Med. Asst.	X-ray Tech	Lab Tech	PA
		Minutes of Personnel Time Required To Produce One Unit of Service*						
Without X-ray	a	7	0	0	0	0	0	0
	b	6	2	0	0	0	0	0
	c	6	0	2	0	0	0	0
	d	0	0	0	0	0	0	7
	e	0	2	0	0	0	0	6
	f	0	0	2	0	0	0	6
Muscle pain	a	16	0	0	0	0	0	0
	b	13	2	0	0	2	0	0
	c	13	0	2	0	2	0	0
	d	13	0	0	2	2	0	0
Burns	a	16	0	0	0	0	0	0
	b	0	0	0	0	0	0	16
	c	13	4	0	0	0	0	0
	d	13	0	4	0	0	0	0
	e	13	0	0	4	0	0	0
	f	0	4	0	0	0	0	13
	g	0	0	4	0	0	0	13
	h	0	0	0	4	0	0	13
Abscess	a	14	0	0	0	0	0	0
	b	12	3	0	0	0	0	0
	c	12	0	3	0	0	0	0
Wound infection	a	10	0	0	0	0	0	0
	b	8	3	0	0	0	0	0
	c	8	0	3	0	0	0	0
	d	8	0	0	3	0	0	0
Arthritis	a	17	0	0	0	0	0	0
	b	15	4	0	0	0	0	0
	c	15	0	4	0	0	0	0
	d	15	0	0	4	0	0	0

* MD = medical doctor; RN = registered nurse; LPN = licensed practical nurse; MED ASST = medical assistant; X-RAY TECH = X-ray technician; LAB TECH = laboratory technician; PA = physician's assistant.

ceptable for delivering the respective service. Table 2 indicates all observed combinations of personnel time for producing services.

Results of the Study

Results of the exploratory study presented here focus on potential productivity gains, health manpower requirements, and optimal delegation of tasks to the P. A. The maximum productivity of the physician's practice with and without a P. A. was examined. This analysis was conducted by increasing proportionately the demand for all medical services until delegation was no longer possible. The physician was assumed to devote 28 hours a week to patient contact in the office practice. Because only 83 per cent of patient visits could be assigned to one of the medical service categories, the physician time constraint was reduced to 23 hours (1,380 minutes) in the analysis.[4]

The results indicate that the productivity of the individual physician might be increased 74 per cent by the use of a physician's assistant. The efficient practice could care for 147 patients using conventional medical workers, while the introduction of a P. A. would enable the practice to meet the demands of 265 patients. These results indicate only the *potential* gains in productivity. If sufficient demand is not generated or if the physician chooses to use the freed time to increase the attention given his patients or to increase his leisure, this potential increase in physician output would not be fully realized. It must further be presumed that the physician has the knowledge necessary to implement the optimal strategy if the potential gains are to be realized.

These productivity estimates were derived under the assumption that the patient visits not classifiable as one of the medical services could be delegated to the same extent as those visits that were classified. An alternative would have been to assume that the unclassified visits could not be delegated at all. Under this alternative, the estimated gain in productivity from introducing a physician's assistant was 49 per cent. The potential gain is reduced because expansion of the practice also involves an increase in the number of undelegatable patients the physician must see. There is no *a priori* or empirical basis for preferring one assumption to the other.[5]

The model was also used to assess the requirements for health manpower. Since optimal utilization of health manpower depends on the scale of the practice, the model was required to specify efficient operation for several different levels of practice activity. The results in Table 3 indicate the increased potential for efficient delegation as the practice expands. The scale and organization of the practice will define the types and configuration of manpower that can be economically utilized. In order to determine manpower requirements, it would be necessary to specify the sizes of constituent practices and to apply the appropriate manpower utilization for each practice size category.

Finally, the analysis examined the appropriate tasks to delegate to the efficiently employed physician's assistant. The model selects those methods for delivering medical services which minimize the cost of nonphysician personnel. The pattern of delegation is obviously dependent upon the scale of practice, with large practices delegating more activities to the physician's assistant. As the practice expands to the maximum feasible number of patient visits, the P. A. gradually assumes responsibility for a total of eight services. These services are: treating warts (and follow-up), removing ear wax, treating sore throats, treating sinusitis, performing well-child examinations, treating minor burns, and treating muscle contusions (without x-ray). The P. A. also provides birth control counseling in conjunction with the physician. Significant productivity increases are obtained by delegating responsibility for a relatively small number of types of patient problems. Furthermore, these delegations are not likely to provoke controversy since they are already in common practice.

Implications for Health Manpower Planning

It is reasonable to ask whether the conclusions drawn from model simulation have

TABLE 3. Staffing Patterns To Meet Selected Patient Loads (Total Minutes of Staff Time)

Number of Visits	100	120	140	160	180	200	240	260
Doctor	1380	1380	1380	1380	1380	1380	1380	1380
LPN	0	0	52	63	71	79	94	102
RN	0	0	90	200	236	251	300	325
Med Asst	47	238	394	450	506	563	641	703
X-ray Tech	0	7	9	11	12	14	16	18
PA	0	0	0	97	282	468	852	1073

TABLE 4. Marginal Cost of Staff per Patient

Number of Patients	Marginal Cost
120	0.11
130	0.48
140	0.74
150	0.78
160	1.06
170	1.06
180	1.06
190	1.06
200	1.06
240	1.08
260	1.25

any predictive significance. The model is avowedly normative, concerned with prescribing the best state of affairs. Only if the optimal program is accompanied by substantial incentives to its fulfillment may it be regarded as descriptive. At least one factor which must be considered in this regard is whether delegation is sufficiently profitable to encourage the use of P. A.'s. The experiments described above provide the basis for determining the costs of delegation on a per patient basis. Table 4 shows the increase in the total costs of operating the practice that results when the practice accepts an additional patient.[6] Predictably, this marginal costs figure rises as the number of patient visits increases, since the practice is forced to substitute higher priced medical assistance in order to meet the expanded demand with the same input of physician time. What is significant, however, is the fact that over the whole range of expansion, the marginal cost of additional patients is but a small fraction of the customary fees of physicians, thus assuring that delegation will be profitable. This conclusion strongly suggests that when legal and other barriers are eliminated, physicians may embrace delegation with enthusiasm.

The fundamental contribution of the model to the health manpower planner is to redirect discussion of manpower requirements from an emphasis on ratios, of medical workers to population, to an emphasis on efficient systems of health care delivery and the implied manpower requirements. It indicates that dramatic increases in physician productivity might be obtained through delegation, thereby reducing the doctor shortage and the need for additional medical schools. A more comprehensive study is necessary to assess the regional or national impact of delegation. It would be necessary to evaluate the geographical and regional variations in the demands placed upon the health care system as well as to determine the potential role of a variety of additional types of physician extenders.

The study also provides insights into the optimal pattern of task delegation. Identifying the appropriate role of the physician's assistant in delivery of medical care contributes to his introduction into the practice as well as to the development of manpower training programs. This information is essential if the medical care system is to realize the potential of new types of allied health personnel. For example, in order to maximize physician productivity it may be necessary to identify some subset of problems which can be completely delegated to an assistant as opposed to having the assistant involved with large numbers of patients in a dependent role.

Extensions of the Model

This exploratory study has investigated the usefulness of a research strategy and has revealed insights into manpower planning and task delegation. However, the conclusions of the analysis should be interpreted in the light of limitations of the model and of the data base. Since the model presented here abstracts from reality in portraying the medical care system, the conclusions must be qualified.

The model assumes that allied health personnel may be hired for any fraction of a week. In the language of the model, they are regarded as continuously variable inputs. To the extent that a physician must hire his staff for full-time periods, the estimated costs of delivering medical care services will be higher than presented above. The model may be made realistic by introducing the restriction that anyone hired must be hired full time. This would affect the pattern of delegation since the practice would attempt to hire staff that could be efficiently employed full time rather than assigning responsibilities to the least costly workers capable of performing them. For example, a registered nurse may be hired rather than a medical assistant to facilitate the use of a full-time professional.

The model treats the demands for services as deterministic. It does not recognize the fact that patients arrive with complaints in a random fashion.[7] The model also assumes that each method for producing a medical service requires a fixed amount of time from each type of medical personnel involved. It is apparent that treatment times and, hence, inputs vary. While these stochastic elements may cancel each other over a day or a week, it is possible to imagine a day when a practice might confront an unusual number of some complaint or when treatment times and, hence, input requirements may be greater than average. In a practice which was already maximally productive, such situations would imply a need for overtime service by the physician and his staff. The probability of excessive overtime might then be weighed against the alternative of scheduling fewer visits for the practice.

The present analysis programs only 28 hours of physician time. This represents the expected (or average) physician-patient contact time. The remainder of the physician's normal work week is devoted to noncontact activities and to down time due to misscheduling of patients. It was conservatively assumed that prior patterns of unused time will be preserved in the model practice. However, the appealing aspect of delegation is that it reduces the problems created by random arrival of patients. To the extent that both the physician and his assistants are capable of treating a complaint, it is easier to respond to unusual demands. Pooling the risk of stochastic arrival of patients by the physician and his P. A. allows them to schedule more patients; the expected patient contact time can rise, the required unused time can go down. Since both are qualified to perform certain activities, they may supplement one another's efforts.

Finally, the data used in the present empirical research is limited in quantity. The demands for medical services have been estimated from information on the services delivered by practices in the upper-Midwest during the summer. It is improbable that identical demands would be observed in other regions or seasons. Consequently, the effects of geographic or seasonal variations in demand upon the optimal program of delegation are not provided for in the study. The significance of this weakness can only be appraised by collecting and analyzing comparable data under a variety of conditions. The data also contain limited information regarding the potential role of the physician's assistant. By defining as methods of delivering care only those observed in the practice survey, many acceptable delegation opportunities were undoubtedly overlooked. More empirical research and the judgments of experts would result in the definition of additional methods for producing medical services. This study suggests that continued effort is justified.

Appendix

This appendix presents the formal model of the primary care practice employed in the study. The model characterizes the practice as a multiproduct firm which transforms inputs of labor, equipment, and materials into specfic medical services. The requirements for nonlabor inputs in producing services are assumed to be invariant over alternative methods; the analysis is consequently simplified to consider only alternative modes of manpower utilization. The model is composed of relations expressing the technological alternatives for producing specific services and describing the demands for services in a representative practice.

Assume that a set of production functions exists, which relate the amounts of M labor inputs, Y_k ($k = 1, \ldots, M$) to the amount of the i^{th} medical service produced, Q_i ($i = 1, \ldots, N$). In general form, these relations may be written:

(1)

$$Q_i = F_i(Y_1, \ldots, Y_M) \qquad i = 1, \ldots, N.$$

It is convenient to specify the production function for each medical service as a set of linear activities where each activity represents a fixed coefficient method defined in terms of the amount of time, of the physician and of each type of medical assistant, which is required to produce one unit of the service. Assume there are a total of R activities, X_r, ($r = 1, \ldots, R$) available for producing all medical services. Each service can be produced by one or more activities, while each activity is associated with only one service. In order to identify each activity with its corresponding service, let the first R_1 activities be methods for producing the first service; the next R_2 activities methods for producing the second service; and, in general, activities $X_{R_{i-1}+1}$ to X_{R_i} methods for producing i^{th} service.

The relation between inputs of labor and outputs of services is made explicit by the technological characteristics of the activities. Associated with unit level operation of each activity ($X_r = 1$) is an inputs requirement vector:

$$a_r = \begin{bmatrix} a_{r1} \\ \vdots \\ a_{rk} \\ \vdots \\ a_{rM} \end{bmatrix}$$

where element a_{rk} is the amount of resource required by activity r in producing one unit of the corresponding service; *e.g.*, the number of minutes that personnel type k must be engaged in order to deliver one unit of the service.

The demand for any output service i may be satisfied by any of the alternative methods of production $X_{R_{i-1}+1}, \ldots, X_{R_i}$. More formally, the total output of any service from all methods of production must equal the required output S_i:

(2)

$$\begin{aligned} X_1 + \ldots + X_{R_1} &= S_1 \\ X_{R_1+1} + \ldots + X_{R_2} &= S_2 \\ &\vdots \\ X_{R_{N-1}+1} + \ldots + X_{R} &= S_N \end{aligned}$$

It is assumed that all medical personnel except physicians are continuously variable factors; the physician is regarded as a fixed resource. Thus, in addition to the output constraints, the firm faces the input restriction that the amount of physician time, Y_1, required by the solution set of activity levels in producing the output mix $S_1, \ldots, S_N$ must not exceed the available supply.

(3)

$$\sum_{r=1}^{R} a_{r1} X_r \leq \overline{Y}_1$$

The objective of the practice is assumed to be the minimization of the cost of hired labor inputs in producing the required services. The model is designed to choose those activity levels, X_r ($r = 1, \ldots, R$) which minimize the variable costs of the practice, where all nonphysician inputs are valued at their market prices p_k ($k = 2, \ldots, M$). The objective is therefore:

$$(4)\qquad \min_{X} \sum_{k=2}^{M} \sum_{r=1}^{R} p_k a_{rk} X_r = \sum_{r=1}^{R} \left[\sum_{k=2}^{M} p_k a_{rk} \right] X_r$$

The term $\sum_{k=2}^{M} p_k a_{rk}$ represents the variable cost of operating the r^{th} activity at unit level. This quantity multiplied by the level of activity r and summed over all activities gives the total variable cost associated with any solution. Note that, since the activities are characterized by fixed coefficients and the market prices of variable factor inputs are taken as given, $p_k a_{rk}$ and therefore $\sum_{k=2}^{M} p_k a_{rk}$ will be constant for each activity.

Finally, it is possible to define the utilization of or demand for each of the variable factors. Straightforward operation of the model yields a solution set of activities $(X_1, \ldots, X_R)$. From this solution one may obtain the demand for variable resource k, $k = 2, \ldots, M$ (representing technicians, nurses, etc.) as:

$$(5)\qquad D_k = \sum_{r=1}^{R} a_{rk} X_r$$

Acknowledgment

The authors wish to acknowledge the valuable comments of Ralph Andreano, Kathleen Charles, Marc Hansen, Allen Kelley, Joanne Masuret, Gregg Miklashek, Louis Pondy, and John Renner. They are also grateful to Marilyn Manser for extensive assistance in computer programming and to David Hendrickson, Candy McKanna, Thomas Norris, Michael Weiner, and Robert Whitehouse for collecting and processing the data. Finally, they thank the physicians whose practices were observed for their cooperation.

References
(Footnotes included)

1. Pediatricians have been at the forefront in examining the potential of task delegation. See for example, Yankauer, A., Connelly, J. P., and Feldman, J. J.: Task Performance and Task Delegation in Pediatric Practice. *Am. J. Public Health*, July, 1969; and Silver, H. K., and Hecker, J. A.: Trends in the Provision of Health Care to Children Through the Utilization of Allied Health Professionals. *The New Physician*, May, 1969.

2. By relieving the physician of the burden of these repetitive activities the quality of care provided might also improve; the physician would be free to devote greater attention to exceptional problems while the extender would be practicing in his relatively narrow, routine specialty.

3. Work sampling techniques were used to observe and record the activity of the practice. See Davidson, H. O., Wittner, W., and Newberry, T. L.: The error of estimate in systematic activity sampling. *Journal of Industrial Engineering* 11 (July-August 1960), pp. 290-292.

4. It is also, of course, necessary to specify the wage that must be paid to each type of medical assistant. The prices of various medical personnel vary substantially because of differences in local labor markets and because of differences in the productivity, real or perceived, of workers with similar formal qualifications. For purposes of this study, the following weekly salaries were assumed: Physician's Assistant—$192; Registered Nurse—$125; Medical Assistant—$58; Licensed Practical Nurse—$81; X-ray Technician—$77; and Laboratory Technician—$144.

5. In subsequent discussions, the assumption of delegability of the unclassified activities is adopted.

6. It should be remembered that when the number of patient visits is increased, the percentage of total visits which fall in each medical service category is unchanged. Thus, the additional patient receives a linear combination of all the medical services.

7. D. H. Uyeno has used a simulation model of pediatric practice to take account of this stochastic feature. "Health Manpower Systems: An Application of the Management Sciences to the Design of Primary Health Care Teams," unpublished dissertation, Northwestern University, 1971.